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Authors
Cristina, Bongiovanni
Chiara, Gori
Benedetta, De Berardinis
et al.

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Utility of a Bedside Pocket-Sized Ultrasound Device to Promptly Manage Abdominal Pain in the Emergency Department

Bongiovanni Cristina¹, Gori Chiara¹, De Berardinis Benedetta¹, Marino Rossella¹, Laghi Andrea², Di Somma Salvatore¹,³ *

¹Department of Medical-Surgery Sciences and Translational Medicine, “Sapienza” University Sant’ Andrea Hospital, Via di Grottarossa, Rome, Italy
²Department of Radiological, Oncological and Pathological Sciences, “Sapienza” University, Viale del Policlinico, Rome, Italy
³Great Network Italy

Abstract

Introduction: Abdominal pain is a frequent reason for Emergency Department (ED) admission; it amounts for around 5–10% of all ED visits. Early assessment should focus on immediately distinguishing cases of acute abdomen that require urgent surgical intervention. The clinical localization of pain is crucial, suggesting an initial evaluation of the origin of the abdominal pain; however, imaging is often required for final diagnosis. Ultrasound (US) represents a rapid imaging modality that is readily available in the ED and does not involve radiation or contrast agent administration. A new generation of portable, battery-powered, low-cost, hand-carried ultrasound devices have become available recently; these devices can provide immediate diagnostic information in patients presenting with abdominal pain in ED. The aim of the study was to demonstrate the diagnostic usefulness of a bedside pocket-sized ultrasound (BPU) device (Vscan from General Electrics) in non-traumatic patients complaining of acute abdominal pain in a tertiary care university hospital in Italy.

Methods: Patients with acute non-traumatic abdominal pain presenting in ED were prospectively enrolled and underwent physical examination, traditional imaging and BPU.

Results: A total number of 230 patients with acute non-traumatic abdominal pain were enrolled. Overall agreement between routine standard imaging and BPU turned out to be equal for computed tomography (K=0.3) and traditional ultrasound (K=0.29). Receiver operating characteristics curve (ROC) analysis for diagnostic power of the BPU in comparison with traditional US showed an area under the curve of 0.65, sensitivity and specificity of 87.2% and 42.31% respectively.

Conclusions: Emergency use of BPU in patients with non-traumatic abdominal pain demonstrated good diagnostic performance when compared to traditional imaging, with the potential advantage of reducing costs and delay in patient final disposition.

Keywords: abdominal pain, computed tomography, diagnosis, emergency department, ultrasound

Correspondence to:
Salvatore Di Somma
Department of Medical-Surgery Sciences and Translational Medicine “Sapienza” University Sant'Andrea Hospital, Via di Grottarossa, 1035/39 - 00189 Rome, Italy and Great Network Italy
Email: salvatore.disomma@uniroma1.it

INTRODUCTION

Abdominal pain is a frequent complaint in the emergency department (ED), and it amounts for 5–10% of all ED visits.¹

It encompasses a wide differential diagnosis that includes medical, surgical and non-surgical diseases that can involve all organs within the torso, abdomen, back and pelvis. Almost 10% of patients...
complaining abdominal pain in the ED have a life-
threatening cause and/or require surgery.²

Immediate assessment should focus on
distinguishing those cases of true acute abdomen
that require urgent surgical intervention from
those that do not, which can initially be managed
conservatively.³–⁵

Patient’s outcome is directly related to early
accurate diagnosis for providing immediate
treatment; however, the final etiology could remain
unknown in about 25% of patients discharged from
ED and for 35% of patients admitted to hospital.³–⁶

Patient history, physical examination, and
laboratory testing may not identify an underlying
cause of pain but could narrow the differential
diagnosis.⁶,⁷

The location of pain should drive the evaluation
of the patient with abdominal pain; however,
imaging is often required for definitive diagnosis
and treatment.⁷,³

Computed tomography (CT) scan provides the
highest sensitivity and specificity of all imaging
modalities for patients with abdominal pain.⁷,⁸ In
particular, in case of discriminating urgent from
non-urgent conditions, the sensitivity for CT is 89%
and the specificity is 77%.⁷

However, CT has major downsides such as the
risk of contrast-induced nephropathy and exposure
to ionizing radiation (a great concern in children
and pregnant patients).⁹

Moreover, CT is expensive and may not be
available at certain times and locations, which
leads to delay in diagnosis and may compromise
management and outcome.⁷,⁸

On the other hand, ultrasound (US) is a rapid and
safe modality, which is widely available, and does
not involve radiation exposure and contrast media
administration.⁷,⁸

When compared with computed tomography,
the sensitivity and specificity of ultrasound are
lower. However, US has clearly demonstrated it is
effective in identifying an accurate diagnosis in 53–
83% of patients when coupled with good clinical
assessment.⁷,¹⁰

Additionally, performing US study and/or CT
scan in the radiology department could be time-
consuming and/or not always possible, especially in
patients with hemodynamic instability and cannot
leave the ED.¹¹–¹³

In the last few years, a new generation of
portable, battery-powered, inexpensive, hand-
carried ultrasound devices has become available;
these devices can provide immediate diagnostic
information not assessable by physical examination
alone and may be useful in diagnosis of some fatal
pathologies especially in overcrowded shifts.¹¹,¹³

The aim of the present study was to demonstrate
the diagnostic usefulness of Vscan (Vscan™, c,
USA) in non-traumatic patients complaining from
acute abdominal pain in our ED by comparing
results of Vscan exams have been compared with
standard radiological methods such as US, CT and
plain films.

MATERIAL AND METHODS

Study design

We conducted this prospective observational
study in a 400-bed tertiary care university hospital
located in a large metropolitan city in Italy with
fifty thousand ED visits per year. The study was
conformed to the Helsinki declaration and approved
by the local ethical committee.

Written informed consent for the study was
obtained from each patient.

Study population

Patients with acute non-traumatic abdominal
pain, age >18 years old and able to give a written
informed consent were considered eligible for the
present study (Figure 1).

We excluded patients unable to give written
consent, with hemodynamic instability or any other
indication for immediate care or surgery, or if they
had a previously diagnosed abdominal pathology.

Patients were triaged according to the presenting
symptoms.

The medical history, the physical examination
and the vital parameters were recorded in the
Patient referring to ED with an acute non traumatic abdominal

Emergency physician clinical assessment

Clinical suspect for:
- Renal colic
- Gallbladder colic
- Cholecystitis
- Abdominal aortic aneurism
- Aortic dissection
- Acute urinary retention
- Ascites

Exclusion criteria
- Clinical suspect for other diseases
- Patient unable to give informed consent
- Patient < 18 years old

Vscan bedside examination (performed by an expert trained resident)
Emergency Physician in charge and Radiologist will be blinded to the

Standard of care examinations
- Abdominal ultrasound
- Abdominal X-Ray
- Abdominal computed tomography

Final Diagnosis

Positive findings at standard of care examinations
- Rule-in
- Misdiagnosis

Negative findings at standard of care examinations
- Rule-in
- Misdiagnosis

Figure 1 Study design.
computerized system. Laboratory tests and diagnostic imaging (X-rays, computed tomography, traditional ultrasound) were performed in a normal goal-directed manner.

A Vscan was performed at the bedside, in the emergency department by ED residents who had completed basic training in ultrasound. This training included two weeks of didactic and hands-on experience under the supervision of experienced faculty certified in ED ultrasonography. The trainees had to successfully perform and complete no less than 50 cases that required them to view image torso, abdomen and pelvis and view kidneys, bladder, liver, gallbladder, spleen and abdominal aorta. Immediately after the bedside US, patients underwent standard imaging provided by a specialist radiologist blinded to the Vscan results.

Different diagnosis was made on the basis of clinical findings as well as diagnostic and laboratory studies. The actual patient management and disposition were never based on the bedside US results alone.

Patients’ diagnoses were encoded in four codes:
- Code 1: for kidney diseases (renal colic, acute urinary retention)
- Code 2: for gallbladder diseases (biliary colic, cholecystitis)
- Code 3: for abdominal aorta diseases and ascites (abdominal aortic aneurysm, aortic dissection, ascites)
- Code 4: for other abdominal diseases.

Data collection

Clinical data, demographic characteristics, comorbidity, length of stay, presenting symptoms and discharge diagnosis, time in the ED, time to perform each diagnostic test, laboratory tests, and time of admission to the hospital were recorded for each patient.

The duration for any “Standard imaging study” was considered as the period, in minutes, between the time of the computerized entry for the study request by the emergency physician (EP) in the centralized electronic health care system and the radiologist’s official written reading for that study. Vscan acquisition time was also measured. It was considered as the period, in minutes, between the time the probe was placed till the moment the exam was completed.

Pocket-sized ultrasound device

Vscan (Vscan™, GE Healthcare, USA) is a new generation pocket-sized ultrasound instrument, miniaturized (unit size: 135x73x28 mm; transducer size: 120 x 33 x 26 mm; weight: 390 g; display resolution: 240 x 320 pixels), battery-operated (total scan time: one hour) with a broad bandwidth (1.7 to 3.8 MHz). Its dimensions fit into a pocket. The device has a unique sectorial probe. The device provides black and white mode to display the anatomy in real-time, uses a color-coded overlay for real-time blood flow imaging and is capable of switching from cardiology to abdominal settings. Vscan can store digital still-frames or image loops in a memory card downloaded on computerized system, allowing distance measurements using integrated electronic calipers.

Statistical analysis

Data points are expressed as mean ± SD. Chi square exact test was used for the comparison of non-continuous variables expressed as proportions. P <0.05 indicates statistical significance. All p values are 2-sided.

The diagnostic performance of bedside abdominal US and of abdominal CT and standard US was assessed by calculating sensitivity, specificity, positive predictive value, negative predictive value and likelihood ratios.

The k statistic was calculated to assess inter-observer agreement of abdominal bedside US and abdominal CT and abdominal standard US.

For the statistical analyses, SPSS software (version 17.0, SPSS Inc., Chicago, IL, USA) was used.

RESULTS

We included 230 patients (M/F= 50/50%; 51.81 ± 17.82 years) with acute non-traumatic abdominal pain in the study. Patients’ characteristics are shown in Table 1.
Table 1: Patients' characteristics.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (M/F)</td>
<td>115/115</td>
</tr>
<tr>
<td>Age (years) (mean ± SD)</td>
<td>51.81 ± 17.82</td>
</tr>
<tr>
<td>ED LOS (hours) (mean ± SD)</td>
<td>15.58 ± 18.21</td>
</tr>
</tbody>
</table>

M: male; F: female; SD: standard deviation; LOS: length of stay

In 76.9% of patients, bedside abdominal US showed significant pathological findings, of those 55.6% had hydronephrosis and/or ureteronephrosis, 14.7% gallbladder-biliary tract diseases, 3.9% free fluid in abdomen, 3.04% abdominal aorta aneurism, 1.7% acute urinary retention (Table 3).

Table 2: Comparison between Vscan and traditional imaging.

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vscan visualization (poor/good)</td>
<td>7.4/92.6</td>
</tr>
<tr>
<td>Traditional imaging visualization (poor/good)</td>
<td>3%/97%</td>
</tr>
<tr>
<td>Traditional imaging acquisition time (minutes) (mean ± SD)</td>
<td>94.8 ± 73.8</td>
</tr>
<tr>
<td>Vscan acquisition time (minutes) (mean ± SD)</td>
<td>4 ± 1</td>
</tr>
</tbody>
</table>

SD: standard deviation

In particular, for diagnosis code 4 (all other causes), results showed a sensitivity (CI95%) of 89.47% (66.86-98.70) and a specificity (CI95%) of 80.00% (28.36-99.49) with an AUC=0.85 for abdominal CT in comparison with Vscan; abdominal US had sensitivity (CI95%) of 91.30% (71.96-98.93) and a specificity (CI95%) of 72.22% (46.52-90.31) with an AUC=0.82.

Table 3: Vscan findings

<table>
<thead>
<tr>
<th>Findings</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydroureteronephrosis</td>
<td>55.6%</td>
</tr>
<tr>
<td>Gallbladder-biliary Tract Disease</td>
<td>14.7%</td>
</tr>
<tr>
<td>Free Fluid In Abdomen</td>
<td>3.9%</td>
</tr>
<tr>
<td>Abdominal Aorta Aneurism</td>
<td>3.04%</td>
</tr>
<tr>
<td>Acute Urinary Retention</td>
<td>1.07%</td>
</tr>
</tbody>
</table>

In code 1 patients (kidney diagnosis), abdominal CT showed a sensitivity (CI95%) of 91.18% (76.32-98.14) and a specificity (CI95%) of 50.00% (1.26-98.74) with an AUC=0.71; abdominal US showed a sensitivity (CI95%) of 86.11% (78.13-92.01) and a specificity (CI95%) of 45.83% (25.55-67.18) with an AUC=0.66.

A subgroup analysis was performed dividing patients as follows: hepatic/gallbladder diseases (including diagnosis code 2 + 4), urinary disease (diagnosis code 1) and abdominal aorta disease (diagnosis code 3).

The higher concordance between bedside US and traditional imaging (K=0.64) was found in the first subgroup (diagnosis code 2 + 4).

Figure 3: Final diagnosis. (Blue: kidney disease; red: gallbladder disease; green: abdominal aorta disease/free fluid in abdomen).
**Table 4** Comparison between Vscan and traditional imaging.

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Vscan</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>NPV</th>
<th>PPV</th>
<th>+LR</th>
<th>-LR</th>
<th>AUC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnosis 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(standard abdominal CT)</td>
<td>89.47% (66.86-98.70)</td>
<td>80.00% (28.36-99.49)</td>
<td>66.67% (22.28-95.67)</td>
<td>94.44% (72.71-99.86)</td>
<td>4.47</td>
<td>0.13</td>
<td>0.85</td>
<td></td>
</tr>
<tr>
<td>Diagnosis 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(standard abdominal US)</td>
<td>91.30% (71.96-98.93)</td>
<td>72.22% (46.52-90.31)</td>
<td>86.67% (59.54-98.34)</td>
<td>80.77% (60.65-93.45)</td>
<td>3.29</td>
<td>0.12</td>
<td>0.82</td>
<td></td>
</tr>
<tr>
<td>Diagnosis 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(standard CT)</td>
<td>91.18% (76.32-98.14)</td>
<td>50.00% (1.26-98.74)</td>
<td>25.00% (0.63-80.59)</td>
<td>96.87% (83.78-99.92)</td>
<td>1.82</td>
<td>0.18</td>
<td>0.71</td>
<td></td>
</tr>
<tr>
<td>Diagnosis 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(standard US)</td>
<td>86.11% (78.13-92.01)</td>
<td>45.83% (25.55-67.18)</td>
<td>42.31% (23.35-63.08)</td>
<td>87.74% (79.94-93.31)</td>
<td>1.59</td>
<td>0.30</td>
<td>0.66</td>
<td></td>
</tr>
</tbody>
</table>

Diagnosis codes: code 1: kidney disease; code 2: gallbladder disease; code 3: abdominal aorta disease and ascites; code 4: others abdominal diseases. All parameters are present at 95% confidence interval; NPV: negative predictive value; PPV: positive predictive value; +LR: positive likelihood ratio; -LR: negative likelihood ratio; AUC: area under the curve.
In the urinary disease subgroup (code 1), concordance between traditional US and Vscan (K=0.31) was better than abdominal CT and Vscan (K=0.28).

No concordance was found in the vascular disease subgroup.

Furthermore, a high statistically significant correlation between bedside ultrasound and both computed tomography (r=0.65; p=0.0006) and traditional ultrasound (r=0.65; p=0.0001) were shown in the first subgroup.

DISCUSSION

Acute abdominal pain is a common presenting symptom in ED visits for conditions ranging from benign to life threatening.1–6 Accurate early diagnosis and treatment are essential to optimize patient outcomes and prevent adverse events.4 In 70% of patients, an urgent diagnosis was correctly identified based on clinical assessment and US.14

The utility and accuracy of bedside US have been established with several studies and it has been incorporated into the training of EPs, however it has not yet included in the international guideline on acute abdominal pain.11–16 The present study demonstrated that bedside abdominal US with Vscan had a good diagnostic performance compared to standard CT and US for patients with abdominal non-traumatic pain due to kidney diseases and other causes of abdominal pain except to vascular and gallbladder related diseases.14–19

This result was totally unexpected at the beginning of our study. The findings are different than those reported in other prior studies that showed excellent diagnostic performance for emergency bedside US to detect the presence of the aortic and gallbladder related diseases in symptomatic patients;11–13,15 this could be related to the small sample, to the level of training and experience of the EP performing the Vscan and/or to the small number of positive findings among the examinations performed.

Moreover, we found a high concordance and correlation between Vscan and traditional imaging in a larger subgroup including hepatogastrointestinal-pancreatic diseases and gallbladder diseases (code 2 + 4). This result must be taken in consideration with standard imaging evaluation patients with abdominal non-traumatic pain.

Furthermore, we demonstrated how bedside US with Vscan could be very quickly used in an acute emergency scenario giving important information that could not be depicted with the clinical assessment alone. In our series bedside US can be performed in 4 ± 1 minutes contemporary with clinical care and complementary to the physical examination. This could lead to significant timesaving for the assessment of an adequate management of patients arriving in ED with acute non-traumatic abdominal pain. In fact, our results demonstrated how an overcrowded ED can lead to a delay in the acquisition time of standard imaging reports, that in our experience was 94.8 ± 73.8 minutes with a subsequent delay in patient disposition (in our study we recorded an ED length of stay of 15.58 ± 18.21 hours).

In our opinion, bedside US with Vscan should be used as part of the initial evaluation of all patients presenting to ED with acute non-traumatic abdominal pain, and that its complementation with clinical assessment will provide improved diagnostic value.

The use of US with Vscan as a complement to routine clinical assessment may avoid misdiagnoses, improve patient satisfaction, and may also reduce costs associated with return visits, additional unnecessary exams or potential adverse events caused by a delayed diagnosis.

Last but not least, bedside ultrasonography may
be particularly valuable in rural and underserved regions where healthcare providers have no access or limited access to CT scans, radiologists or formal ultrasonography. This is of special relevance to developing nations where such access is invariably absent or compromised.

LIMITATIONS

This study has some limitations. First, the analysed sample is small. Second, the majority of patients had kidney disease (69% of our sample) with a consequent underrepresentation of other relevant abdominal diseases such as gallbladder and abdominal aorta diseases that could represent an important spectrum bias in this study.

Finally, this was an observational study; therefore, EPs did not have the possibility to use the results of the Vscan examination to change their decision-making process. This prevented investigators from quantifying the effective timesaving and cost reduction in such a patient population.

CONCLUSION

Emergency bedside US with Vscan in patients with non-traumatic abdominal pain had demonstrated good diagnostic performance, when compared to traditional radiology imaging.

Bedside US can be performed and interpreted by EPs and it could represent an important tool to reduce time in clinical decision-making, improve patient outcome and reduce time and costs to patients when compared with traditional radiological exams. Conflict of Interest: The author declared receiving a fund from General Electrics to conduct this study.

REFERENCES

